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(54) WELL TELEMETRY WITH AUTONOMOUS ROBOTIC DIVER

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See application file for complete search history.

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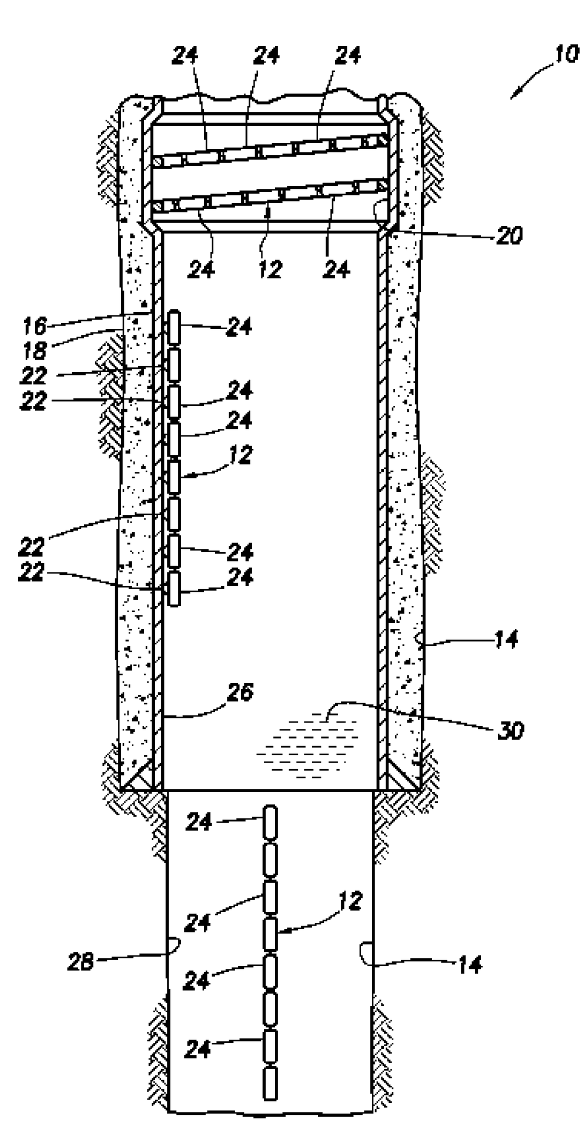
(57) **ABSTRACT**

A telemetry apparatus for use in a well can include multiple segments, the segments comprising at least one buoyancy control device, at least one telemetry device, and at least one articulation device that controls a relative orientation between adjacent ones of the segments. A method of communicating in a subterranean well can include installing at least one telemetry apparatus in the well, the telemetry apparatus comprising a telemetry device and a buoyancy control device, and the telemetry device communicating with another telemetry device at a remote location. A well system can include at least one telemetry apparatus disposed in a wellbore, the telemetry apparatus comprising multiple segments, the segments including at least one buoyancy control device and at least one telemetry device.

10 Claims, 5 Drawing Sheets



(51) **Int. Cl.**

E21B 47/18	(2012.01)
E21B 47/12	(2012.01)
E21B 47/00	(2012.01)
E21B 49/00	(2006.01)

(52) **U.S. Cl.**

CPC ***E21B 47/18*** (2013.01); *E21B 47/00* (2013.01); *E21B 49/00* (2013.01)

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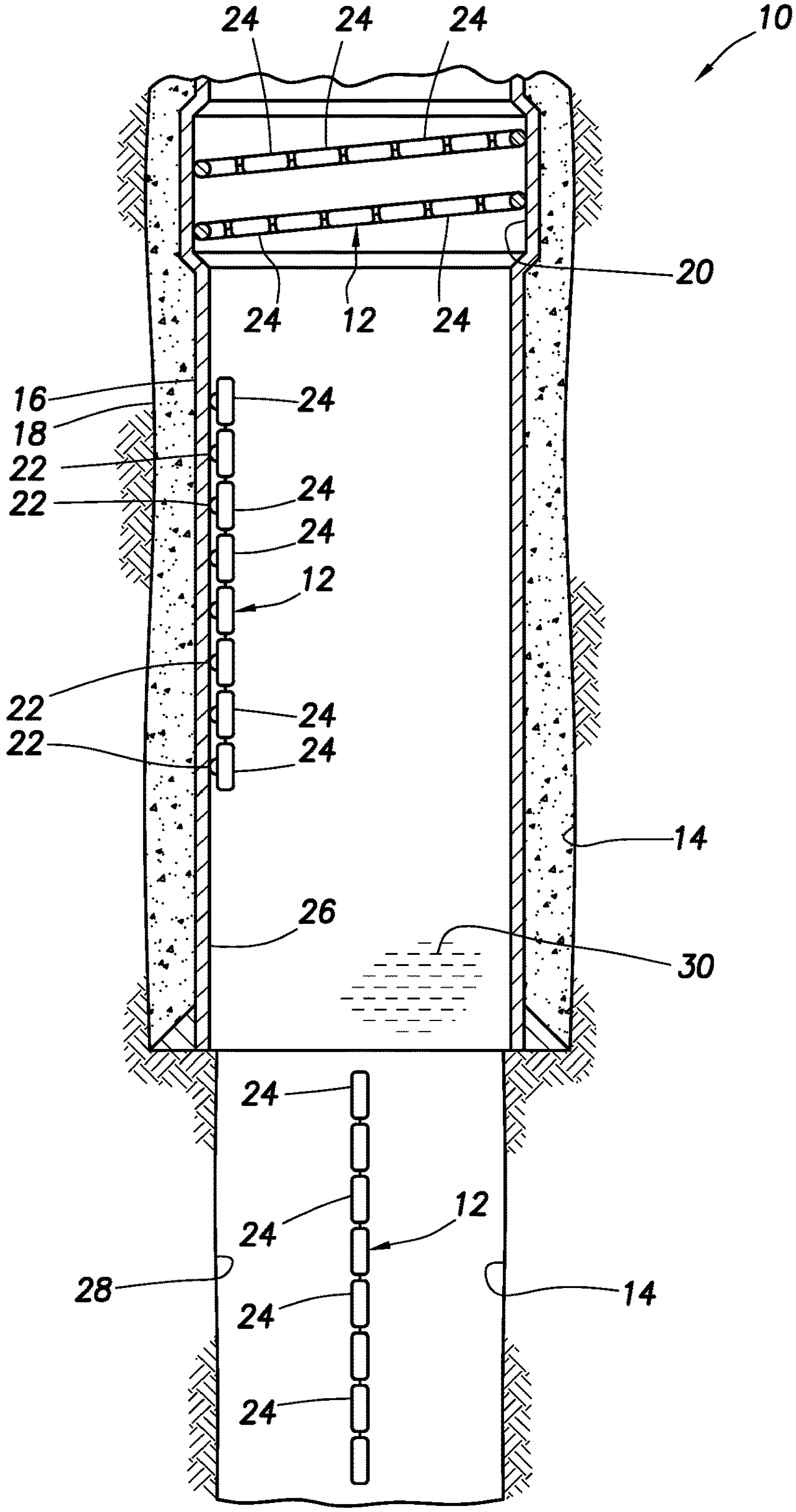

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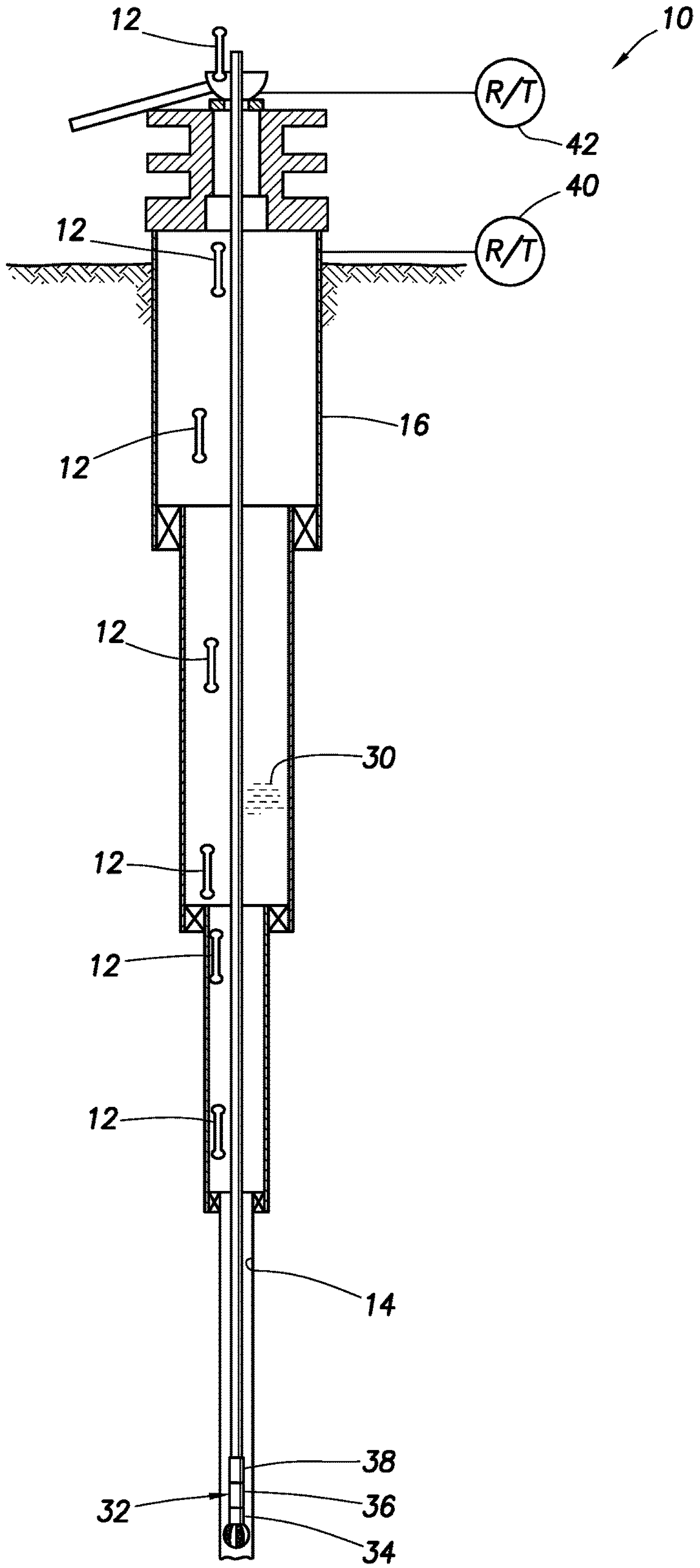
FIG. 1

FIG.2



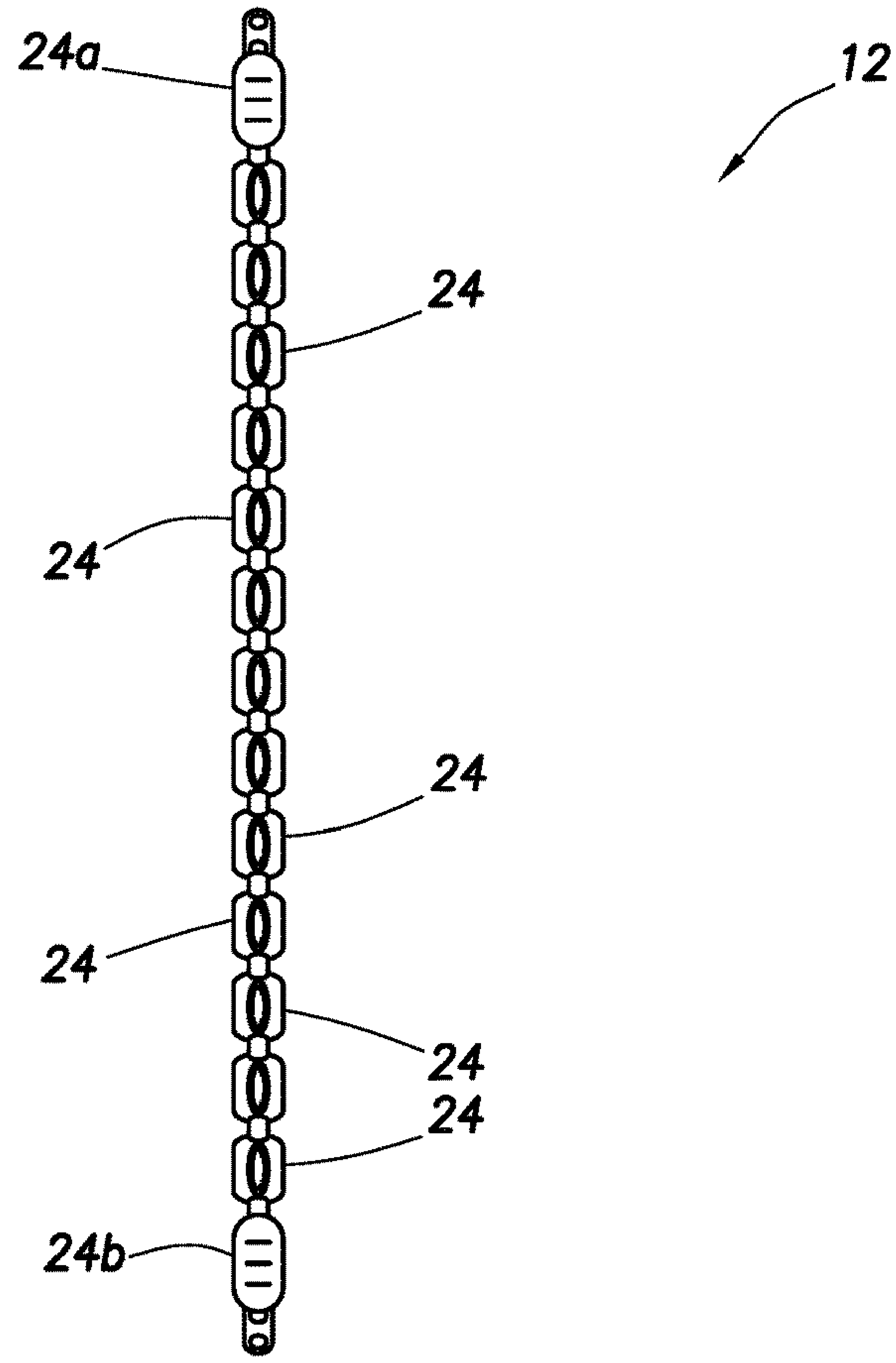


FIG.3

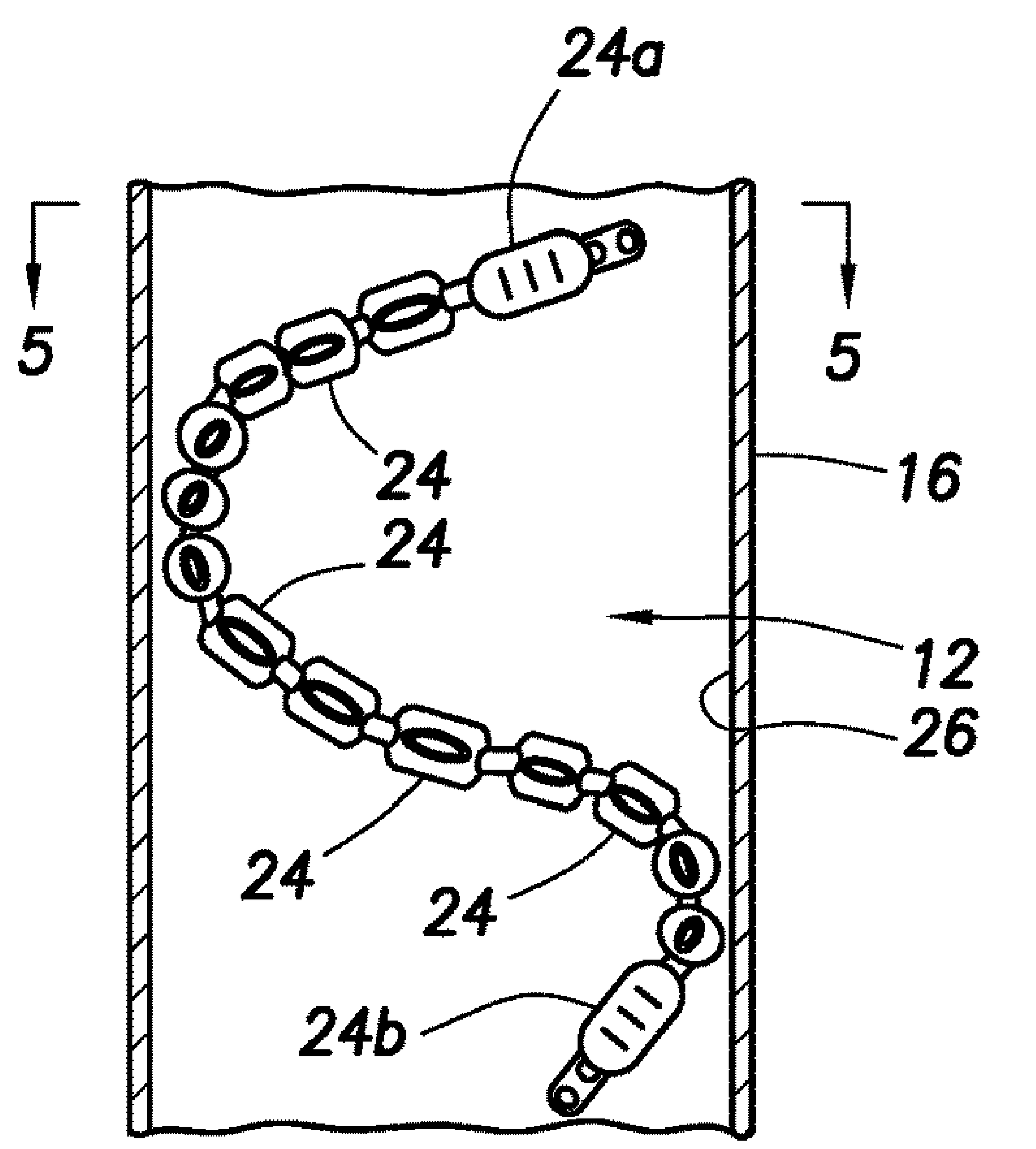


FIG.4

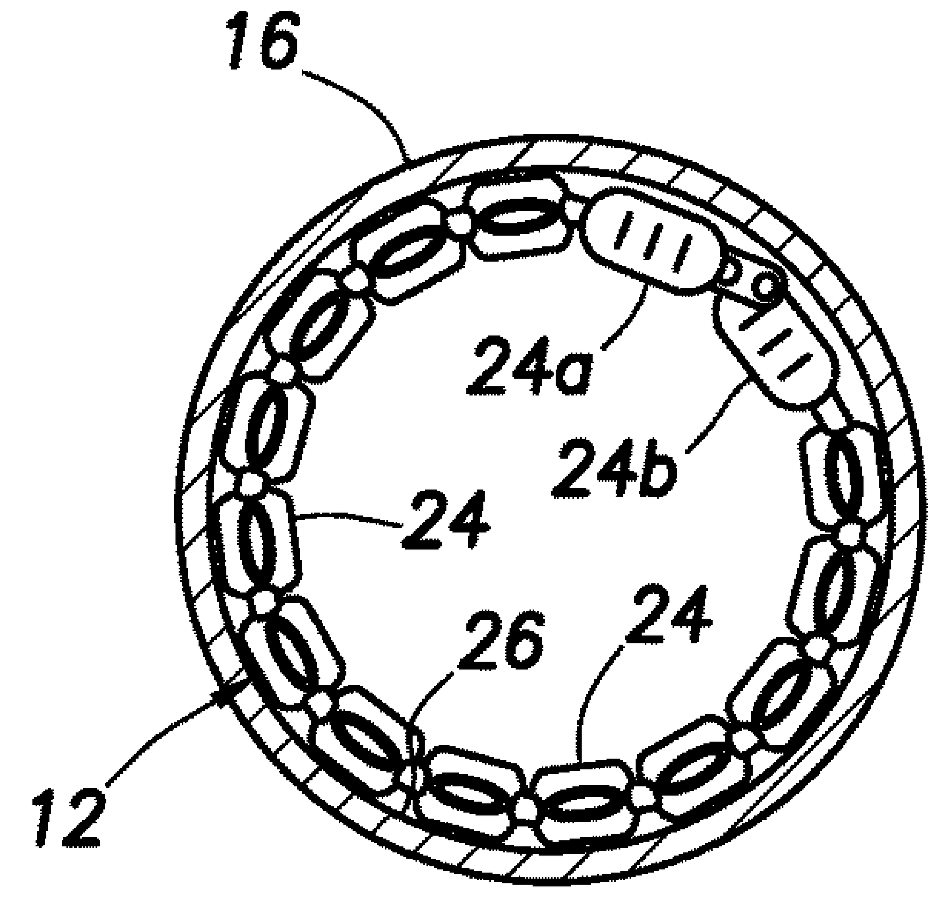


FIG.5

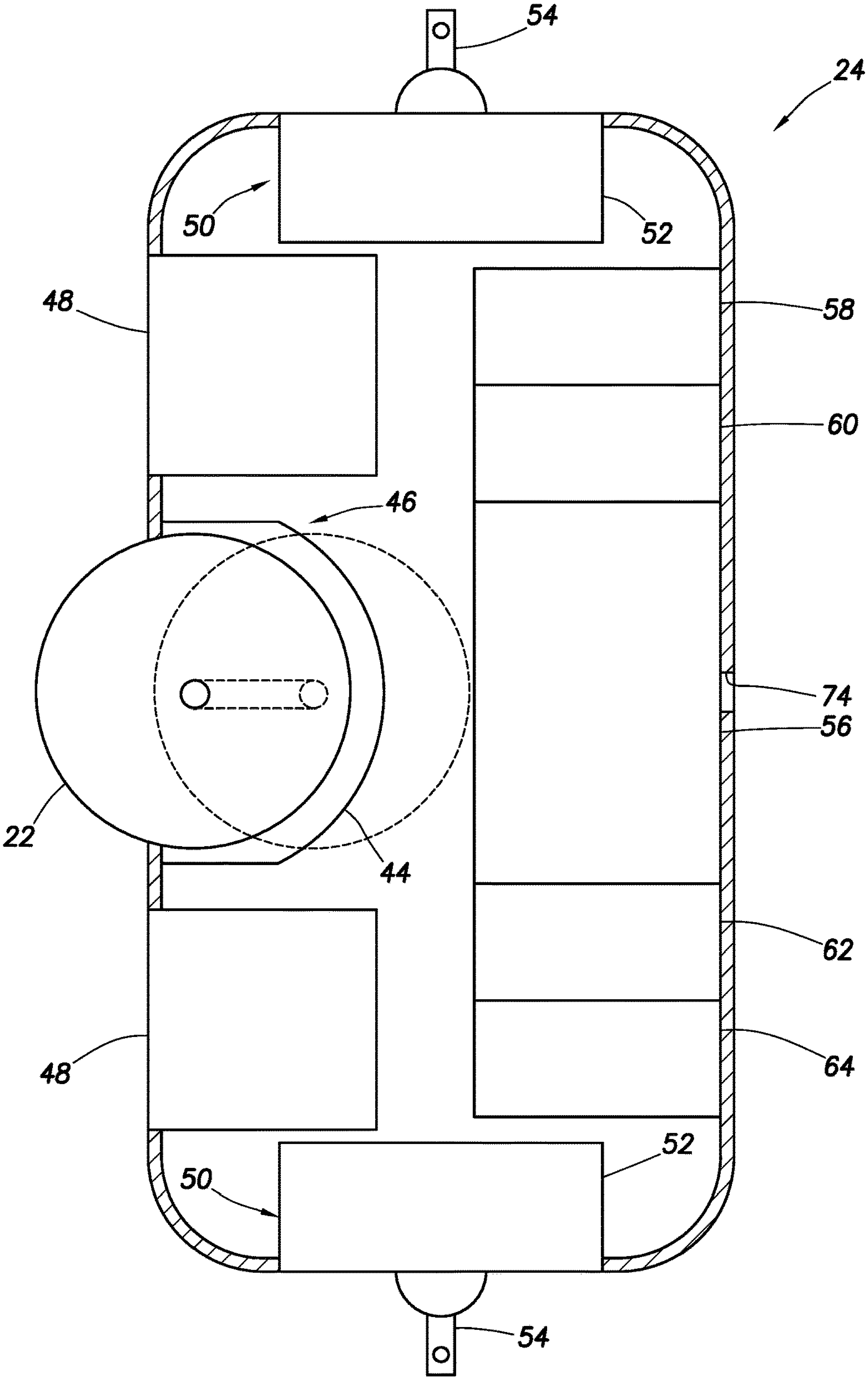


FIG.6

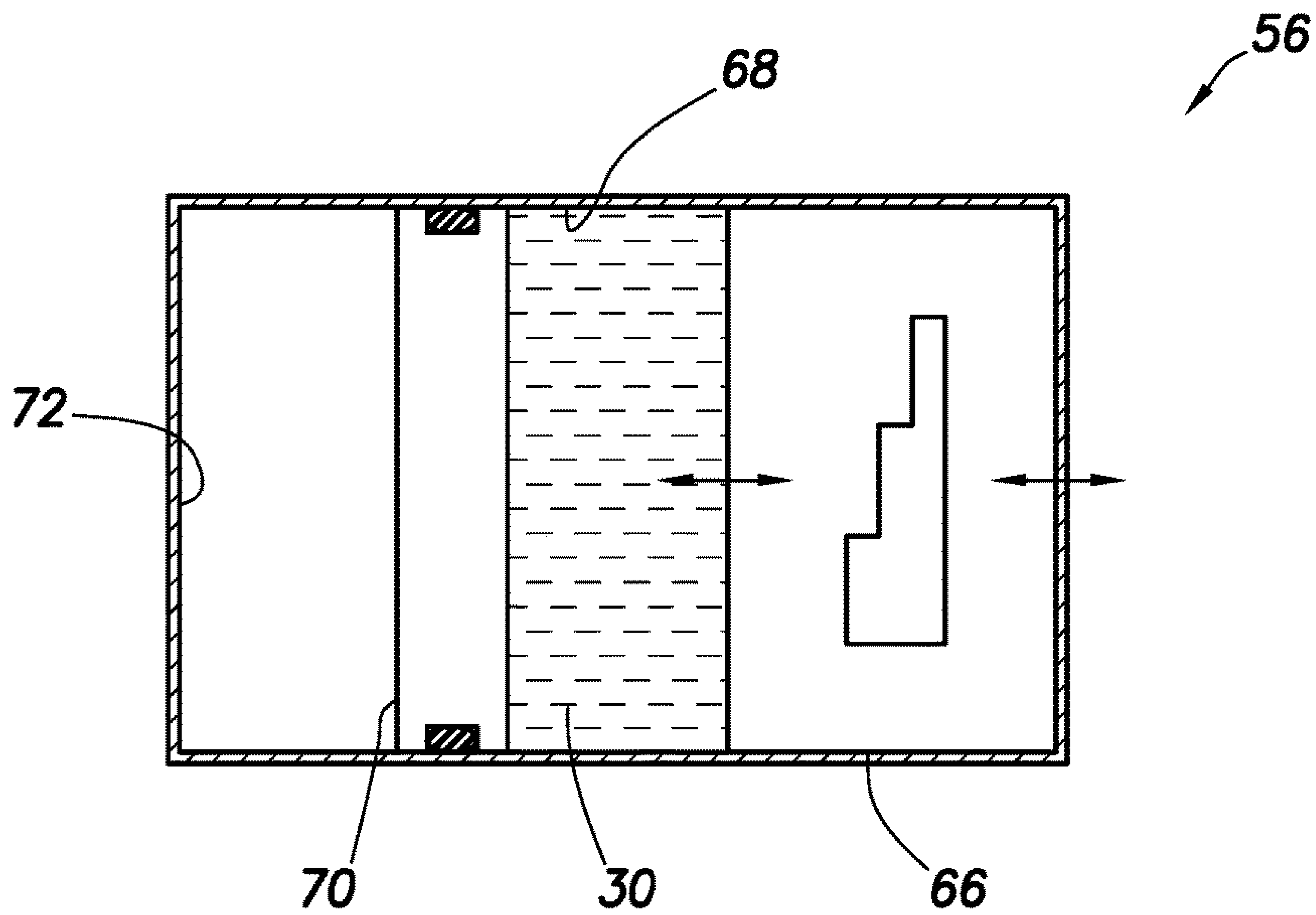


FIG.7

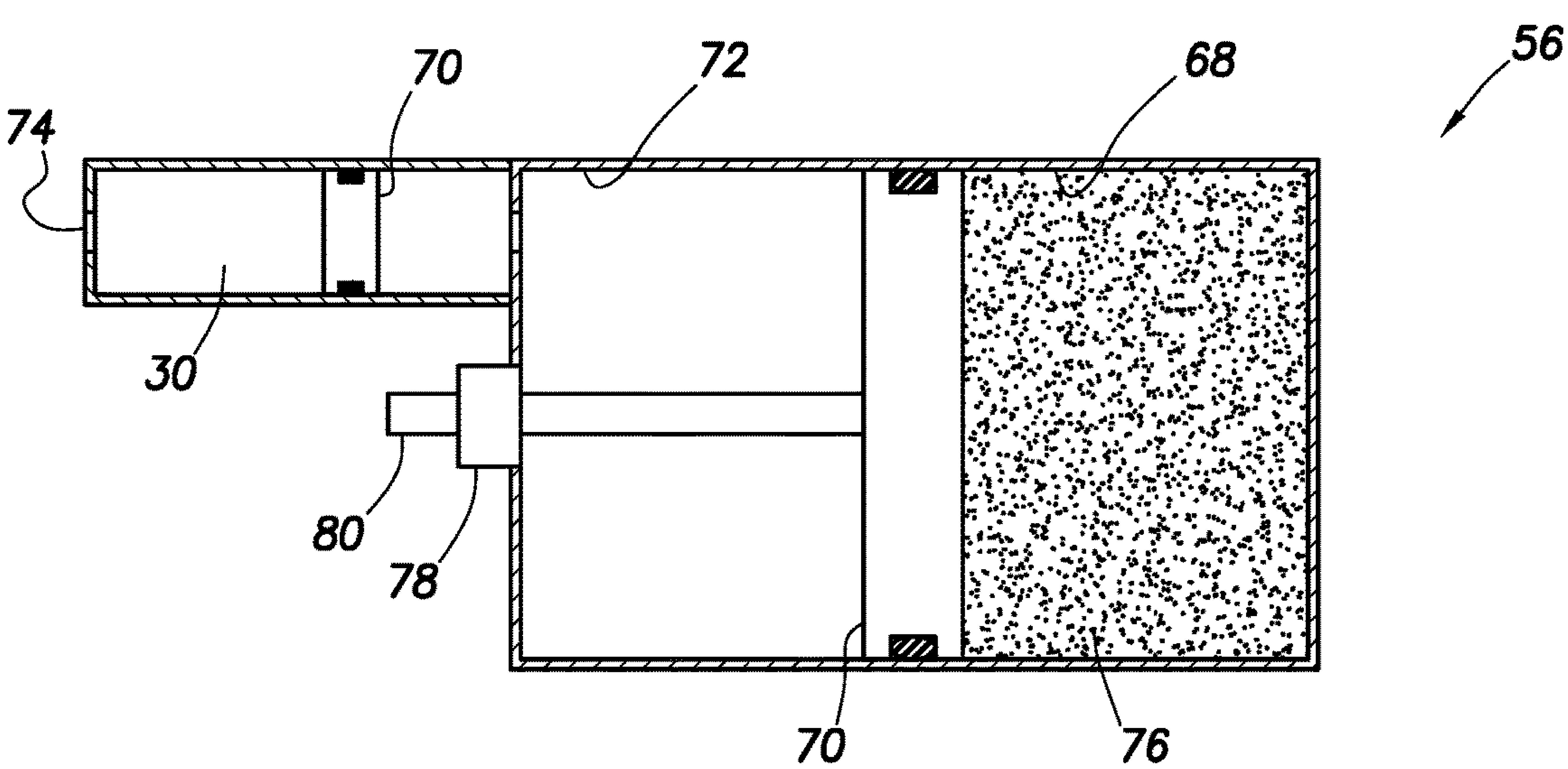


FIG.8

WELL TELEMETRY WITH AUTONOMOUS ROBOTIC DIVER

TECHNICAL FIELD

This disclosure relates generally to equipment utilized and operations performed in conjunction with a subterranean well and, in one example described below, more particularly provides for telemetry in a well using an autonomous robotic diver apparatus.

BACKGROUND

It is beneficial to be able to communicate with sensors, actuators or other devices in wells. For example, sensor measurements can be received at a surface location, without a need to retrieve a sensor from a well. In another example, a command can be sent to a downhole device, in order to cause the device to perform a particular function. Therefore, it will be appreciated that improvements are continually needed in the art of well telemetry.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a representative partially cross-sectional view of an example of a well system and associated method which can embody principles of this disclosure.

FIG. **2** is a representative partially cross-sectional view of another example of the system and method.

FIG. **3** is a representative side view of an example of a telemetry apparatus that may be used in the system and method, the telemetry apparatus being depicted in a linear configuration thereof.

FIG. **4** is a representative partially cross-sectional view of the telemetry apparatus in a helical arrangement in a casing.

FIG. **5** is a representative cross-sectional view, taken along line **5-5** of FIG. **4**.

FIG. **6** is an enlarged scale representative partially cross-sectional view of a segment of the telemetry apparatus.

FIGS. **7** & **8** are representative schematic views of a buoyancy control device that may be used in the telemetry apparatus.

DETAILED DESCRIPTION

Representatively illustrated in FIG. **1** is an example of a system **10** for use with a well, and an associated method, which system and method can embody principles of this disclosure. However, it should be clearly understood that the system **10** and method are merely one example of an application of the principles of this disclosure in practice, and a wide variety of other examples are possible. Therefore, the scope of this disclosure is not limited at all to the details of the system **10** and method described herein and/or depicted in the drawings.

In the FIG. **1** example, multiple telemetry apparatuses **12** are installed in a wellbore **14**. It is not necessary, however, for there to be multiple telemetry apparatuses **12** in the wellbore **14**, since the principles of this disclosure could be practiced with only a single apparatus in the wellbore.

The wellbore **14** as depicted in FIG. **1** has an upper section lined with casing **16** and cement **18**, and a lower section that is uncased or open hole. In other examples, the entire wellbore **14** could be cased. The apparatuses **12** could be positioned in any cased and/or uncased sections of the wellbore **14**, in keeping with the principles of this disclosure.

As used herein, the term "casing" indicates a generally tubular protective wellbore lining. Casing may be made up of tubulars of the type known to those skilled in the art as casing, liner or tubing. Casing may be segmented or continuous. Casing may be pre-formed or formed in situ. Thus, the scope of this disclosure is not limited to use of any particular type of casing.

As used herein, the term "cement" indicates an initially flowable substance that hardens to form a seal in a well. Cement is not necessarily cementitious, since other types of cement can include epoxies or other hardenable polymers, composites, etc. Cement may harden due to hydration of the cement, passage of time, application of heat, contact with a hardening agent, or any other stimulus. Cement may be used to secure a casing in a wellbore and seal off an annulus formed between the casing and the wellbore. Cement may be used to seal off an annulus formed between two tubular strings. Cement may be used to seal off a passage extending through a tubular string. Thus, the scope of this disclosure is not limited to use of any particular type of cement, or to any particular use for cement.

In the FIG. **1** example, the telemetry apparatuses **12** are depicted in different configurations. An upper one of the apparatuses **12** is helically arranged in a radially enlarged recess **20** formed in the casing **16**. This can be considered a "parked" apparatus **12**, in that the apparatus can remain motionless in the recess indefinitely.

Positioned in the recess **20**, the apparatus **12** does not obstruct operations (such as, drilling, stimulation, completion, production or workover operations, etc.) that may be performed in the wellbore **14**. Although the recess **20** is depicted in FIG. **1** as being formed in the casing **16**, in other examples recesses may be formed by, for example, underreaming a cased or uncased section of the wellbore **14**.

The recess **20** or a shoulder could be in or above a liner or tubing hanger (see, for example, FIG. **2**). Thus, the scope of this disclosure is not limited to use of the recess **20** as depicted in FIG. **1**.

The apparatus **12** can leave and return to the recess **20** at any time. Examples of ways the apparatus **12** can displace through the wellbore **14** are indicated by the middle and lower apparatuses **12** depicted in FIG. **1**. However, it is not necessary for the apparatus **12** to be positioned in, or to displace to or away from, a recess in keeping with the scope of this disclosure.

The middle apparatus **12** depicted in FIG. **1** can displace by means of motor-driven wheels **22** extending laterally outward from segments **24** of the apparatus. The wheels **22** engage an inner surface **26** of the casing **16**. If the casing **16** is made of a ferrous material, the wheels **22** could be biased into contact with the surface **26** using magnetic attraction.

If the middle apparatus **12** of FIG. **1** were instead positioned in an uncased section of the wellbore **14**, the apparatus could assume a helical configuration, in order to bias the wheels **22** into contact with an inner surface **28** of the wellbore. Of course, if the wellbore **14** is inclined or horizontal, gravity can bias the wheels **22** into contact with the surfaces **26**, **28**.

The lower apparatus **12** depicted in FIG. **1** displaces through the wellbore **14** due to a difference in density between the apparatus and fluid **30** in the wellbore. A buoyancy of the apparatus **12** is increased to cause the apparatus to rise through the fluid in the wellbore **14**, and the buoyancy of the apparatus is decreased to cause the apparatus to descend through the fluid in the wellbore.

As described more fully below, "parking" of one or more apparatuses **12** in the wellbore **14** (whether or not in the recess **20**) and/or displacement of one or more apparatuses through the wellbore can provide for effective telemetry of sensor measurements, other data, commands, or other types of communication of information. In addition, the apparatuses **12** can displace or remain at any location in the wellbore **14**, either autonomously, automatically and/or in response to commands transmitted from a remote location (such as, a surface control station, a subsea communication station, a bottom hole assembly, a water or land based rig, etc.).

In the FIG. **1** example, each of the apparatuses **12** comprises multiple segments **24**. The segments **24** are articulable relative to one another, so that the apparatus **12** can take on various configurations (such as, the linear and helical arrangements depicted in FIG. **1**). However, the scope of this disclosure is not limited to use of the articulated segments **24** in the apparatus **12**.

Referring additionally now to FIG. **2**, another example of the system **10** and method is representatively illustrated. In this example, multiple telemetry apparatuses **12** are installed in the wellbore **14**, in order to provide for communication between a bottom hole assembly **32** and a surface location.

The bottom hole assembly **32** in the FIG. **2** example is a drilling assembly comprising a drill bit **34**, one or more sensors **36** (such as, pressure, temperature, torque, weight on bit, flow, resistivity, density, fluid type and/or other types of sensors) and a telemetry device **38**. In other examples, the bottom hole assembly **32** could be another type of assembly (such as, a stimulation, completion or production assembly, etc.), and the assembly could include other or different elements (such as, a drilling motor, a reamer, a stabilizer, a steering device, etc.). Thus, the scope of this disclosure is not limited to use of any particular bottom hole assembly configuration.

The telemetry device **38** of the bottom hole assembly **32** may be any type of telemetry device capable of communicating with one of the apparatuses **12**. For example, pressure pulse, acoustic, electromagnetic or any other type of telemetry may be used. The telemetry device **38** may only transmit information, or may both transmit and receive information. The scope of this disclosure is not limited to use of any particular type of telemetry device **38** in the bottom hole assembly **32**.

A well environment can be noisy, and interference with communications can be caused by flowing fluids and particles, presence of ferrous materials, pipes rotating or otherwise displacing in casing, etc. Thus, communicating over large distances can be difficult, impractical or impossible.

In the FIG. **2** example, by positioning one of the apparatuses **12** in relatively close proximity to the bottom hole assembly **32**, the apparatus can more effectively communicate with the telemetry device **38**. In addition, multiple apparatuses **12** can be distributed along the wellbore **14**, so that each apparatus can effectively communicate with a telemetry device above and below that apparatus.

However, in some circumstances (such as, drilling operations), a position of the bottom hole assembly **32** can change over time, and so positions of the apparatuses **12** can also change over time. In some examples, the apparatuses **12** can be provided with "intelligence" allowing them to select appropriate spacings between them, so that effective communication is maintained as well conditions change.

For example, a first apparatus **12** introduced into the wellbore **14** may descend until it can effectively communicate with the telemetry device **38** of the bottom hole assembly **32**. The apparatus **12** can then maintain a position that is at a distance no greater than that at which effective communication is maintained.

A second apparatus **12** introduced into the wellbore **14** can then descend until it can effectively communicate with the first apparatus **12**. The second apparatus **12** can then maintain a position that is at a distance no greater that that at which effective communication with the first apparatus can be maintained.

This process can be repeated until a sufficient number of apparatuses **12** have been introduced into the wellbore **14**, so that the last apparatus can effectively communicate with one or more telemetry devices **40**, **42** at a remote location (such as, the earth's surface, a subsea location, a water or land based rig, etc.). Additional apparatuses **12** can be introduced into the wellbore **14** as needed to maintain effective communication between the telemetry device **38** of the bottom hole assembly **32** and the telemetry device(s) **40**, **42** at the remote location.

Thus, the apparatuses **12** function to relay information between the telemetry device **38** and the telemetry device(s) **40**, **42**. In addition, the intelligence of the apparatuses **12** can be used to vary spacings between the apparatuses as needed to maintain effective communication.

For example, the spacings are not necessarily equal if more interference or noise exists in one section of the wellbore **14** as compared to other sections of the wellbore.

As another example, the spacings can change if levels of interference or noise change over time, or if the location of the bottom hole assembly **32** changes over time.

In the FIG. **2** example, the apparatuses **12** displace through the wellbore **14** in response to buoyancy changes. The apparatuses **12** do not necessarily include the articulated segments **24** depicted in the FIG. **1** example. However, the FIG. **2** apparatuses **12** could include the articulated segments **24**, and could displace through the wellbore **14** by other means (such as, the motorized wheels **22** depicted in FIG. **1**), in keeping with the principles of this disclosure.

The intelligence of the apparatuses **12** can be used to control their buoyancies, and to adapt to different densities of fluid **30** in the wellbore **14**. Thus, the buoyancy of each apparatus **12** can be adjusted autonomously and automatically as needed to either maintain a selected position in the wellbore **14**, or to rise or descend in the wellbore.

Referring additionally now to FIG. **3**, an example of the telemetry apparatus **12** is representatively illustrated, apart from the system **10** and method of FIGS. **1** & **2**. The apparatus **12** of FIG. **3** may be used the system **10** and method of FIGS. **1** & **2**, or it may be used in other systems and methods, in keeping with the principles of this disclosure.

In the FIG. **3** example, the apparatus **12** comprises the multiple articulated segments **24**. The segments **24** are arranged in a linear configuration. In this linear configuration, the apparatus **12** can most rapidly displace along the wellbore **14** (see FIGS. **1** & **2**), and can traverse obstructions, narrow passages, etc.

Note that it is not necessary for all of the segments **24** of the apparatus **12** to be identical to each other. In the FIG. **3** example, an upper segment **24***a* and a lower segment **24***b* are different from segments **24** between the upper and lower segments.

For example, the upper and lower segments **24***a,b* could include telemetry devices (not shown, see FIG. **6**), whereas the middle segments **24** may not include telemetry devices. As another example, the upper segment **24***a* could include a buoyance device (not shown, see FIG. **6**) for changing a buoyancy of the apparatus **12**, whereas the other segments **24**, **24***b* may not include buoyancy control devices. Thus, the scope of this disclosure is not limited to use of any particular configuration or combination of configurations of apparatus segments **24**, **24***a,b*.

Referring additionally now to FIGS. **4** & **5**, the apparatus **12** is representatively illustrated in a helical configuration. The apparatus **12** is positioned in the casing **16**, and the helical configuration enables the apparatus to effectively adapt to the casing's inner diameter and contact the inner surface **26** of the casing.

In the helical configuration, the apparatus **12** can maintain a selected position in the casing **16**, for example, to enable long term "parking," to monitor well parameters at the position over time, to recharge batteries (not shown, see FIG. **6**), or for other purposes. The scope of this disclosure is not limited to any particular purpose for maintaining the apparatus **12** at a certain position for an extended period of time in the helical configuration.

In the helical configuration, the apparatus **12** can also displace helically along the inner surface **26** of the casing **16** (or along the surface **28** of the wellbore **14**, see FIG. **1**), for example, using the motorized wheels **22** (see FIG. **1**) and/or buoyancy changes. By displacing deliberately along the inner surface **26** of the casing **16**, or along the surface **28** of the wellbore **14**, sensors of the apparatus **12** (not shown, see FIG. **6**) can sense certain well parameters along the wellbore (such as, casing integrity, cement to casing bond, flow behind casing, resistivity, density, pressure, temperature, fluid density, viscosity, etc.).

With helical displacement of the apparatus **12**, it will be appreciated that a higher azimuthal resolution of sensor measurements can be obtained, and measurements can be obtained more completely about the casing **16** and wellbore **14**, as compared to linear displacement of the apparatus along the wellbore. However, sensor measurements can be obtained with the apparatus **12** in the linear configuration (see FIG. **3**), in keeping with the principles of this disclosure.

In one example of the method, the apparatus **12** can initially descend in a linear configuration and then, upon striking an obstruction (such as, a bridge plug or a bottom of the wellbore **14**) the apparatus can change to the helical configuration. A buoyancy of the apparatus **12** can then increase, so that the apparatus (with or without assistance of the motorized wheels **22**) will ascend helically along the wellbore **14** while recording/transmitting sensor measurements.

In another example, the apparatus **12** can have a built-in casing collar locating capability to ensure counting casing collars as the apparatus descends in a linear configuration. When the apparatus **12** counts a pre-programmed number of casing collars (and the apparatus is, thus, at a desired depth), the apparatus can change to the helical configuration.

In another example of the method, the apparatus **12** (or multiple apparatuses) can be initially wrapped about a tubular string (such as, a drill string or a production string) when it is deployed in the well. Then, the apparatus **12** can "unwind" from the tubular string and displace to an appropriate position in the well.

One example of using the apparatus **12** to facilitate communication between a bottom hole assembly (BHA) and surface is in logging while drilling (LWD) operations. Mud pulse telemetry can suffer from severe noise interference at surface due to high noise levels generated by surface equipment, resulting in low signal-to-noise ratio and decreased signal detection. A mud pulse telemetry receiver could be included with the apparatus **12** positioned at a location away from the surface, where the impact of surface noise is significantly reduced. Once BHA data is decoded by the apparatus **12**, the data can then be recoded and telemetered to surface.

In an another example, such as in drill stem testing or well intervention operations, it can be desirable to send sensor data across packers or other well obstructions. One apparatus **12** can be positioned below the obstruction, and another apparatus **12** can be positioned above the obstruction, in order to relay data through the obstruction. Once the data is received above the obstruction, the apparatus **12** can communicate the data to the surface via conventional telemetry means, such as, acoustic telemetry, wireline, electromagnetic telemetry, etc.

Referring additionally now to FIG. **6**, an enlarged scale partially cross-sectional view of one example of a segment **24** of the apparatus **12** is representatively illustrated. The segment **24** depicted in FIG. **6** may be used for the upper segment **24***a*, the lower segment **24***b* or any other segment **24** of the apparatus **12**. However, it should be clearly understood that the segment **24** depicted in FIG. **6** is merely one example of a particular segment configuration, and a wide variety of other examples may be used, in keeping with the principles of this disclosure.

In the FIG. **6** example, the segment **24** includes the wheel **22**, which is rotated by a motor **44**. The motor **44** may also include an actuator (not shown) for inwardly retracting the wheel **22**. For example, if the apparatus **12** is displacing through the wellbore **14** (see FIGS. **1** & **2**) in the linear configuration due to a buoyancy change, or if the apparatus is parked or otherwise maintaining its position in the wellbore, then the wheel **22** may not be needed and can be retracted.

The wheel **22** and motor **44** can be considered an engagement device **46** for engaging a well surface (such as, the inner surface **26** of the casing **16**, the surface **28** of the wellbore **14**, etc.). In some examples, the wheel **22** could be magnetized or made of a magnetic material, so that the wheel is biased into contact with the casing surface **26** or another well surface due to magnetic attraction.

Alternatively, or in addition, one or more magnetic engagement devices **48** (such as, permanent magnets and/or electromagnets, etc.) may be included in the segment **24** to bias the segment toward a well surface due to magnetic attraction. If the wheel **22** is extended, the magnetic attraction can be used to bias the wheel into contact with the well surface. If the wheel **22** is retracted, the magnetic attraction can be used to secure the apparatus **12** in position (that is, to prevent displacement of the apparatus along the wellbore **14**).

The FIG. **6** segment **24** example also includes an articulation device **50** at each opposite end of the segment. The articulation devices **50** are used to control relative orientation between the segment **24** and adjacent segments connected at the opposite ends of the segment. Of course, if the segment **24** is at either opposite end of the apparatus **12**, then there is only one adjacent segment, and so only one articulation device **50** may be used.

The articulation device **50** in the FIG. **6** segment **24** example includes an actuator **52** and a connecting arm **54**. The actuator **52** is used to displace the arm **54** and thereby control the orientation of the segment **24** relative to an adjacent segment connected to the arm.

The actuator **52** can displace the arm **54** in three dimensions, in two dimensions, in one dimension, rotationally, longitudinally, laterally or in any other manner, in keeping with the principles of this disclosure. In some examples, the actuator **52** may comprise piezoelectric, magnetostrictive, electrostrictive, or other types of electromagnetically active materials, although conventional servos, solenoids or other types of motion-producing mechanisms may be used, if desired.

The FIG. **6** segment **24** example also includes a buoyancy control device **56**, a power source **58**, a computing device **60**, one or more sensors **62** and a telemetry device **64**. The buoyancy control device **56** is used to maintain or change a buoyancy of the segment **24** and thereby maintain or change a buoyancy of the overall apparatus **12** as needed to maintain or change a position of the apparatus in the wellbore **14** (see FIGS. **1** & **2**). Examples of the buoyancy control device **56** are depicted in FIGS. **7** & **8**, and are described more fully below.

The buoyancy control can be coordinated with well operations. For example, in a drilling operation, the apparatus **12** may be parked during actual drilling. When drilling fluid flow is stopped (such as, during a drill pipe connection make-up), the apparatus **12** can descend to a position closer to the bottom hole assembly **32** (see FIG. **2**) if needed, or multiple apparatuses can adjust their spacing for optimal data transmission. The apparatuses **12** would again park upon resumption of drilling fluid flow.

The power source **58** is used to provide electrical power to the various other electrical devices of the segment **24**. The power source **58** may include batteries and/or an electrical generator. If an electrical generator is included, the generator may generate electrical power in response to fluid flow, heat, or other stimulus in the wellbore **14**.

The computing device **60** is used to control operation of the other devices of the segment **24**, to store and process sensor measurements, and to otherwise embody the "intelligence" of the segment. In the FIG. **6** example, the computing device **60** controls operation of the engagement devices **46**, **48**, the articulation devices **50**, the buoyancy control device **56** and the telemetry device **64**, stores and processes measurements made by the sensors **62**, and stores and executes instructions (e.g., in the form of software, firmware, etc.) for the various functions performed by the computing device. The computing device **60** can include at least one processor and at least one memory (e.g., volatile, non-volatile, erasable, programmable, etc., memory) for executing and storing instructions, data, etc.

The sensors **62** are used to measure well parameters of interest. The sensors **62** can include pressure, temperature, resistivity, density, fluid type and composition, fluid density, viscosity, acoustic, electromagnetic, optical or any other type of sensors. Pressure measurements may be used to inform and/or modify buoyancy control. Accelerometers, gyroscopes, etc. may be used to determine position and navigate in the well. The scope of this disclosure is not limited to use of any particular type or combination of sensors.

The telemetry device **64** is used to transmit and receive signals comprising sensor measurements, other data, handshake protocols, commands, other information, etc. The signals may comprise pressure pulse, acoustic, electromagnetic, optical or any other type or combination of telemetry signal. The telemetry device **64** may be capable of switching from one type of telemetry signal reception or transmission to another type of telemetry signal reception or transmission. The scope of this disclosure is not limited to use of any particular type of telemetry device.

Referring additionally now to FIG. **7**, an example of the buoyancy control device **56** is representatively and schematically illustrated, apart from the remainder of the segment **24** of FIG. **6**. However, the buoyancy control device **56** of FIG. **7** may be used with other segments, in keeping with the principles of this disclosure.

In the FIG. **7** example, the buoyancy control device **56** includes a positive displacement pump **66** that transfers well fluid **30** between an exterior of the segment **24** and a chamber **68** (for example, via a port **74** in the segment, see FIG. **6**). A floating piston **70** sealingly separates the chamber **68** from a gas-filled chamber **72**.

As the pump **66** fills the chamber **68** with the fluid **30**, the chamber **72** decreases in volume, and the buoyancy of the segment **24** decreases. Conversely, as the pump **66** discharges fluid **30** from the chamber **68** to the exterior of the segment **24**, the chamber **72** increases in volume, and the buoyancy of the segment **24** increases.

It will be appreciated that the FIG. **7** depiction of the buoyancy control device **56** is simplified and a wide variety of variations are possible. For example, the piston **70** could be replaced with a membrane, bladder or other type of displaceable fluid barrier. Instead of using the pump **66**, the piston **70** could be displaced by a motor (not shown) to control the relative volumes of the chambers **68**, **72**. Thus, the scope of this disclosure is not limited at all to any of the details of the buoyancy control device **56** depicted in FIG. **7**.

Referring additionally now to FIG. **8**, another example of the buoyancy control device **56** is representatively illustrated. In this example, the volume of the chamber **72** is controlled by controlling a volume of a substance **76** in the chamber **68**. The volume of the substance **76** may change in response to any stimulus (such as, heat, electrical or magnetic input, etc.). A latching device **78** engaged with a rod **80** attached to the piston **70** may be used to maintain a desired position of the piston.

It may now be fully appreciated that the above disclosure provides significant advancements to the art of communicating in a well. The telemetry apparatus **12** in certain examples described above is capable of relaying information between downhole and surface telemetry devices **38**, **40**, **42**, or between itself and surface telemetry device(s) **40**, **42**, does not require any tether (such as, a wireline, slickline, control line, optical line, etc.), and can operate autonomously to achieve effective communication in a well.

A telemetry apparatus **12** for use in a well is provided to the art by the above disclosure. In one example, the telemetry apparatus **12** can comprise multiple segments **24**, the segments including at least one buoyancy control device **56**, at least one telemetry device **64**, and at least one articulation device **50** that controls a relative orientation between adjacent ones of the segments **24**. The segments **24** are not necessarily identical to each other.

The segments **24** can include at least one engagement device **46**, **48** that engages a well surface **26**, **28**. The engagement device **48** may comprise a magnetic device. The engagement device **46** may comprise a motorized wheel **22**.

The segments **24** can include a sensor **62** that measures a well parameter. The segments **24** may be helically arranged, linearly arranged, or otherwise arranged.

The "at least one" articulation device **50** may comprise multiple articulation devices. Each of the segments **24** can comprise one or more of the articulation devices **50**.

Also provided to the art by the above disclosure is a method of communicating in a subterranean well. In one example, the method comprises: installing at least one telemetry apparatus **12** in the well, the telemetry apparatus comprising a first telemetry device **64** and a buoyancy control device **56**; and the first telemetry device **64** communicating with a second telemetry device **38**, **40**, **42** at a remote location (such as, a remote location in the well, a surface location, a subsea location, a water or land based rig, etc.).

The method can include the telemetry apparatus **12** displacing in the well in response to the buoyancy control device **56** changing a buoyancy of the telemetry apparatus **12**.

The "at least one" telemetry apparatus **12** can comprise multiple telemetry apparatuses, and method can include the telemetry apparatuses **12** distributing themselves in the well, with spacings between the telemetry apparatuses being at most maximum spacings having effective communication between the telemetry devices **64** of successive ones of the telemetry apparatuses **12**.

The second telemetry device **38** may be disposed in a bottom hole assembly **32**, and the method can include the second telemetry device **38** receiving measurements from a sensor **36** of the bottom hole assembly **32** and transmitting the sensor measurements to the first telemetry device **64**.

The second telemetry device **40**, **42** may be disposed at a surface location, and the method can include the second telemetry device **40**, **42** receiving sensor measurements from the first telemetry device **64**.

The telemetry apparatus **12** may comprise multiple segments **24**, and the method can include changing relative orientations between adjacent ones of the segments **24** in the well. The changing step can comprise helically arranging the segments **24**.

A well system **10** is also described above. In one example, the system **10** can comprise: at least one telemetry apparatus **12** disposed in a wellbore **14**, the telemetry apparatus comprising multiple segments **24**, the segments including at least one buoyancy control device **56** and at least one telemetry device **64**.

The segments **24** may include at least one articulation device **50** that controls a relative orientation between adjacent ones of the segments. The segments **24** may include at least one engagement device **46**, **48** that engages a surface **26**, **28** in the wellbore **14**.

The "at least one" telemetry apparatus **12** may comprise multiple telemetry apparatuses. The telemetry apparatuses **12** may be distributed in the wellbore **14**, with spacings between the telemetry apparatuses being at most maximum spacings having effective communication between the telemetry devices **64** of successive ones of the telemetry apparatuses.

The telemetry apparatus **12** may displace in the wellbore **14** in response to a change in buoyancy of the telemetry apparatus.

Although various examples have been described above, with each example having certain features, it should be understood that it is not necessary for a particular feature of one example to be used exclusively with that example. Instead, any of the features described above and/or depicted in the drawings can be combined with any of the examples, in addition to or in substitution for any of the other features of those examples. One example's features are not mutually exclusive to another example's features. Instead, the scope of this disclosure encompasses any combination of any of the features.

Although each example described above includes a certain combination of features, it should be understood that it is not necessary for all features of an example to be used. Instead, any of the features described above can be used, without any other particular feature or features also being used.

It should be understood that the various embodiments described herein may be utilized in various orientations, such as inclined, inverted, horizontal, vertical, etc., and in various configurations, without departing from the principles of this disclosure. The embodiments are described merely as examples of useful applications of the principles of the disclosure, which is not limited to any specific details of these embodiments.

In the above description of the representative examples, directional terms (such as "above," "below," "upper," "lower," etc.) are used for convenience in referring to the accompanying drawings. However, it should be clearly understood that the scope of this disclosure is not limited to any particular directions described herein.

The terms "including," "includes," "comprising," "comprises," and similar terms are used in a non-limiting sense in this specification. For example, if a system, method, apparatus, device, etc., is described as "including" a certain feature or element, the system, method, apparatus, device, etc., can include that feature or element, and can also include other features or elements. Similarly, the term "comprises" is considered to mean "comprises, but is not limited to."

Of course, a person skilled in the art would, upon a careful consideration of the above description of representative embodiments of the disclosure, readily appreciate that many modifications, additions, substitutions, deletions, and other changes may be made to the specific embodiments, and such changes are contemplated by the principles of this disclosure. For example, structures disclosed as being separately formed can, in other examples, be integrally formed and vice versa. Accordingly, the foregoing detailed description is to be clearly understood as being given by way of illustration and example only, the spirit and scope of the invention being limited solely by the appended claims and their equivalents.

What is claimed is:

1. A telemetry apparatus for use in a well, the telemetry apparatus comprising:

multiple segments, wherein the multiple segments are directly coupled to each other, the multiple segments comprising:

at least one buoyancy control device,

at least one telemetry device,

at least one engagement device that engages a well surface, wherein the engagement device biases the telemetry apparatus toward an inner surface of the well, and

at least one articulation device that controls a relative orientation between adjacent ones of the segments, wherein the at least one articulation device comprises an actuator and a connecting arm, wherein the telemetry apparatus is arranged in a helical shape against the inner surface of the well by changing the relative orientation between the multiple segments.

2. The telemetry apparatus of claim **1**, wherein the engagement device comprises a magnetic device.

3. The telemetry apparatus of claim **1**, wherein the engagement device comprises a motorized wheel.

4. The telemetry apparatus of claim **1**, wherein the segments further comprise a sensor that measures a well parameter.

5. The telemetry apparatus of claim **1**, wherein the at least one articulation device comprises multiple articulation devices, and wherein each of the segments comprises at least one of the multiple articulation devices.

6. A method of communicating in a subterranean well, the method comprising:

disposing a first telemetry apparatus in the well, the first telemetry apparatus comprising a first telemetry device and a buoyancy control device, wherein the first telemetry apparatus comprises multiple segments, wherein the multiple segments are directly coupled to each other wherein the first telemetry apparatus comprises an engagement device that engages a well surface, wherein the engagement device biases the first telemetry apparatus toward an inner surface of the well;

displacing the first telemetry apparatus in the well in response to the buoyancy control device changing a buoyancy of the first telemetry apparatus;

changing the relative orientations between the multiple segments, wherein the multiple segments form a helical shape against the inner surface of the well, wherein the helical shape causes the first telemetry apparatus to remain motionless;

disposing a second telemetry apparatus in the well, the second telemetry apparatus comprising a second telemetry device and the buoyancy control device, wherein the second telemetry apparatus comprises multiple segments, wherein the multiple segments are directly coupled to each other, wherein the second telemetry apparatus comprises an engagement device that engages a well surface, wherein the engagement device biases the second telemetry apparatus toward the inner surface of the well;

displacing the second telemetry apparatus in the well in response to the buoyancy control device changing a buoyancy of the second telemetry apparatus;

changing the relative orientations between the multiple segments, wherein the multiple segments form a helical shape against the inner surface of the well, wherein the helical shape causes the second telemetry apparatus to remain motionless; and

transmitting a signal from the first telemetry device to the second telemetry device.

7. A well system, comprising:

at least one telemetry apparatus disposed in a wellbore, the telemetry apparatus comprising multiple segments, wherein the multiple segments are directly coupled to each other, wherein the multiple segments can change orientations relative to each other, wherein the multiple segments comprise:

at least one buoyancy control device;

at least one engagement device that engages a wellbore surface, wherein the engagement device biases the at least one telemetry apparatus toward an inner surface of the wellbore; and

at least one telemetry device, wherein the at least one telemetry apparatus is arranged in a helical shape against the inner surface of the wellbore by changing the relative orientation between the multiple segments.

8. The well system of claim 7, wherein the segments further include at least one articulation device that controls a relative orientation between adjacent ones of the segments.

9. The well system of claim 7, wherein the well system comprises multiple telemetry apparatuses, and wherein the telemetry apparatuses are distributed in the wellbore, with spacings between the telemetry apparatuses being at most maximum spacings having effective communication between the telemetry devices of successive ones of the telemetry apparatuses.

10. The well system of claim 7, wherein the telemetry apparatus displaces in the wellbore in response to a change in a buoyancy of the telemetry apparatus.

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